**Vitamin C content and sensorial properties of dehydrated carrots
blanched conventionally or by ultrasound**

Running title: **Vitamin C and sensorial properties of dehydrated carrots**

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ABSTRACT

Vitamin C content and sensorial properties have been evaluated in air-dried carrots previously subjected to different ultrasound (US) or conventional blanching pretreatments. In addition, mass spectral fingerprints obtained by the Headspace ChemSensor System have been evaluated for the first time for classification of carrots according to their processing. Conventional blanching treatments at high temperature gave rise to carrots with retention of vitamin C in the range 37.5-85%, whereas carrots blanched conventionally at 60°C and by US-probe at temperatures up to 60 and 70°C showed vitamin C retention values lower than 4%. Regarding sensorial analysis of rehydrated carrots, US-pretreated samples presented acceptable quality, and no statistically significant differences with respect to conventionally blanched carrots, were detected. In spite of this, differentiation of samples processed under comparable intensity conditions and/or with similar composition was possible from their mass spectral fingerprints after chemometric data analysis.

Keywords:

Dehydrated carrot, blanching, ultrasound, vitamin C, sensorial properties, ChemSensor (MS-electronic nose), mass spectrometry, classification.

1. Introduction

Carrot (*Daucus carota* L.) is considered one of the vegetables whose consumption, both fresh and processed, has increased over the past years due not only to the nutritional and health benefits this vegetable provides, but also to the introduction of new carrot-derived products (Alasalvar, Grigor, Zhang, Quantick & Shahidi, 2001). In addition, its pleasant flavour is one of the main reasons for its acceptance by consumers; volatiles (mainly terpenes and sesquiterpenes) and sugars being the main compounds that account for the distinctively carrot-like flavour (Alasalvar et al., 2001).

Among the different processes that can be applied to fresh carrot to obtain a product with longer shelf life and/or new characteristics, dehydration by hot-air is probably the most popular (Prakash, Jha & Data, 2004). While the shelf-life might be increased up to one year after dehydration, the quality of dehydrated vegetables might also be negatively affected as compared to that of fresh foodstuff (Negi & Roy, 2001).

Apart from drying conditions (temperature, air-rate, etc), other previous and subsequent sample treatments might affect the quality of the final product (Negi & Roy, 2001). In this respect, blanching is one of the most commonly used pre-treatments to inactivate the enzymes responsible for quality deterioration of processed carrots and it can be carried out under high temperature (Shivhare, Gupta, Basu & Raghavan, 2009) or low temperature (Mohamed & Hussein, 1994) conditions. However, similarly to other thermal processes, blanching and drying have been described to affect several nutritive and bioactive compounds of vegetables including, among others, their vitamin C content (Drake, Spayd & Thompson, 1981). Moreover, both processes can also modify the quality of carrot flavour as a consequence of changes in volatile and sugar profile after these operations (Shamaila, Durance & Girard, 1996; Soria, Sanz & Villamiel, 2008).

Application of alternative blanching methods and/or optimization of drying conditions may result in processed carrots with better flavour, nutritive and bioactive characteristics. Ultrasound (US) blanching has recently emerged as a pretreatment with positive results on the effective water diffusivity of fruits mainly processed by osmotic dehydration (Fernandes, Rodrigues, Law & Mujumdar, 2011). In the case of carrots, hardly any research has been carried out on the potential of US as an alternative to conventional blanching. Rawson, Tiwari, Tuohy, O'Donnell and Brunton (2011) reported higher retention of carotenoids and polyacetylenes in dried carrots subjected to a pre-treatment with a US probe (10 min under pulsed mode) than in dried carrots blanched at 80°C for 3 min. More recently, Gamboa-Santos, Montilla, Soria and Villamiel (2012) have compared the effect of different conventional blanching methods (water and steam water) and US pre-treatments on enzyme inactivation and leaching losses in carrots. Samples blanched for 10 min by US-probe with generation of heat (temperature up to 60 °C) showed similar characteristics to those conventionally treated at 60 °C for a longer time (40 min).

Carrot aroma is generated by a number of volatile compounds of different functionality usually present at very low concentrations; relative volatile composition being dependent on carrot variety, harvesting conditions, pre-processing, processing and storage conditions, etc (Soria et al., 2008). Carrot volatiles have also been described to be highly correlated with different sensory attributes such as odour, taste and aftertaste and with consumer liking (Varming et al., 2004).

Although the common approach for carrot classification according to its volatile composition usually consists of the application of different fractionation techniques for isolation/preconcentration of volatiles previous to their GC-MS analysis (Shamaila et al., 1996; Soria et al., 2008), new methodologies based on direct sampling-mass

spectrometry (DS-MS) have been recently reported for this purpose (Marsili, 2011; Peña, Cárdenas, Gallego, & Valcárcel, 2002). In DS-MS, headspace volatiles sampled directly into the mass spectrometer give rise to a characteristic chemical fingerprint (mass spectrum corresponding to the global volatile profile) for every sample. The use of chemometrics for interpretation of patterns from these multivariate data allows fast and precise classification of samples according to different criteria. Thus, DS-MS has been used for classification of different olive oil classes (Peña, Cárdenas, Gallego, & Valcárcel, 2002) and of wines (Dirinck, Van Leuven, & Dirinck, 2006), among others. Regarding carrots, this methodology has only been applied for discrimination of diseases of stored carrots (Vikram, Lui, Hossain, & Kushalappa, 2006), and no study has yet addressed the application of DS-MS for classification of carrots according to their processing. Advantages of this methodology include minimal sample preparation and high throughput as no prior chromatographic separation is required.

In view of the studies cited above, the main objectives of the present work were: (i) the evaluation in hot-air dried carrots of changes in vitamin C retention and in sensorial properties associated with a previous treatment by US or conventional blanching; (ii) the study of mass spectral fingerprints obtained by the Headspace ChemSensor System (MS-electronic nose) for classification of carrot samples according to their processing.

2. Materials and methods

2.1. Sample preparation

Fresh carrots (*Daucus carota* L. var. Nantesa) were taken from a single batch that was purchased at one time in a local market in Madrid (Spain). Carrots were stored at 4°C for less than a week until processing. Carrots were properly washed in tap water to remove external impurities. Then, samples were cut into slices of 24 mm diameter and 4 mm thickness and as minced carrots (1-2 mm).

2.2. Blanching

Table 1 summarizes all conventional and US blanching treatments carried out on carrot samples. Processing conditions and sample geometry were chosen on the basis of optimal results in terms of enzyme inactivation and leaching losses previously reported by Gamboa-Santos et al. (2012).

2.2.1. Ultrasound treatments

For US treatments, samples of 40 g were placed into 250-mL Erlenmeyer flasks filled with 200 mL of distilled water and were sonicated using an ultrasonic system (450 Digital Sonifier, Branson Ultrasonics Cooperation, Danbury, CT, USA). This sonicator was equipped with a temperature sensor and a tip of 13 mm diameter directly attached to a disruptor horn (20 kHz, 400 W full power) which was immersed 2 cm in the liquid. Experiments were carried out with generation of heat: US blanching for 10 min at temperatures up to 60°C (USP60-10), and for 15 min at temperatures up to 70°C (USP70-15). The ultrasonic density, calculated according to Jambrak, Mason, Paniwnyk and Lelas (2007), was 0.26 W/cm³.

2.2.2. Conventional treatments

Using the same carrot - distilled water ratio as above mentioned, carrot samples were subjected to blanching with boiling water for 1 min (CB-1), with water at 95°C for 5 min (C95-5) and at 60°C for 40 min (C60-40) using a hot-plate with temperature control (IKA RCT Basic Labortechnik, Staufen, Germany). Carrot sample CS-2 was pretreated by steam blanching for 2 min using an autoclave (CERTOCLAV CV-EL GS, Austria) operating under atmospheric pressure conditions.

All assays (US and conventional) were performed in duplicate. After treatments, samples were cooled in an ice-water bath and conveniently drained and dried with absorbent paper to remove the excess of distilled water.

2.3. Drying procedure

In order to evaluate the contribution of air-drying to changes in bioactivity and sensory properties of carrots, additional experiments by convective drying were carried out on samples previously subjected to either conventional or US blanching (Table 1).

Blanched carrot samples (80 g) were dried using a computer controlled (Edibon Scada Control and Data Acquisition Software) air tray-dryer (SBANC, Edibon Technical Teaching Units, Spain). This system consists of three main sections: (i) fan unit with control of the air-flow rate, (ii) control of temperature (seven thermo-hygrometers, ST1-ST7) and (iii) drying compartment (load cell with four drying trays). ST7 was chosen as the process temperature since it was the wet bulb closest to the samples. ST7 registered a temperature of 46 °C by setting the resistance thermometer at a temperature of 60 °C. The air-flow was parallel to the samples and the air-rate was selected with the AVE sensor at 4.9 m/s. During the drying process, the weight of the

samples was automatically monitorized by using the load cell of the system. Minced carrots were dried for 7 h and sliced carrots for 9 h.

The dry matter (DM) content of carrots was gravimetrically determined by drying the samples in a conventional oven at 102 °C until constant weight, according to the AOAC method (950.01, 1990). After drying, all samples presented DM contents within the range 85-89%.

2.4. Determination of vitamin C

The procedure employed to determine total vitamin C (ascorbic acid plus dehydroascorbic acid) was the reduction of dehydroascorbic acid to ascorbic acid, using D,L-dithiothreitol as reducing reagent (Plaza, Sanchez-Moreno, Elez-Martínez, de Ancos, Martín-Belloso & Cano, 2006). Carrot extracts were prepared by adding 12.5 mL of 0.4% oxalic acid to 0.25 g of carrot samples and homogenizing for 1 min at 13500 rpm using an Ultra-Turrax T-25 homogenizer (IKA Labortechnik, Janke & Kunkel, Saufen, Germany). Oxalic acid was used to inhibit further degradation of vitamin C (Erle, 2001). After addition of 2.5 mL of a 5 mg/mL solution of D,L-dithiothreitol, carrot extracts were kept at room temperature in the darkness for 30 min. Once the volume of the slurries was made up to 25 mL with Milli-Q water, they were centrifuged at 3200g for 5 min. The supernatant was filtered through 0.45 µm syringe filters. Carrot extracts were made in duplicate.

Total vitamin C content of carrots was determined by liquid chromatography with diode array detector (RP-HPLC-DAD) on an Agilent Technologies 1220 Infinity LC System – 1260 DAD (Boeblingen, Germany). The separation of vitamin C was carried out with an ACE 5 C₁₈ column (ACE[®], UK) (250 mm, 4.6 mm i.d., 5 µm)

thermostated at 25 °C, using 5 mM KH₂PO₄ at pH 3.0 as the mobile phase. Elution was done under isocratic conditions at a flow rate of 1 mL/min for 10 min. Injection volume was 20 µL and data acquisition and processing were performed using the Agilent ChemStation software (Agilent Technologies, Germany).

Quantitation was performed by the external standard method, using a commercial standard of ascorbic acid (Sigma) in the range 0.3-50 mg/L. Determination coefficient obtained from this calibration curve, which was linear over the range studied, was $R^2 = 0.999$. Chromatographic repeatability ($n=5$) and method repeatability ($n=2$) were estimated and the relative standard deviation (RSD) calculated was below 3%. Results were expressed as milligrams of total vitamin C per 100 g DM.

Data were subjected to analysis of variance (Fisher's least significance difference (LSD) test) by applying the Statgraphics 4.0 program (Statistical Graphics Corporation, Rockville, Md) for Windows.

2.5. Sensory evaluation

After drying, carrot samples were rehydrated in boiling water for 10 min using a sample:water ratio of 1:30 (Prakash, Jha & Data, 2004). The sensory analyses of these samples were carried out by a taste panel of 14 semi-trained judges who were familiarized with samples, attributes and their definitions during two orientation sessions.

A triangle test procedure (ISO Standard 4120) was followed. Panellists were presented with 2 groups of 3 samples each, distributed so that in each group 2 samples were the same and another was different in a randomized order. Panellists were asked to identify the odd sample, paying special attention to the taste and texture. Rehydrated

carrot samples were also evaluated in a hedonic test. Two different sessions were performed: D-C60-40 and D-USP60-10 carrot samples were coded and presented at random order to the panellists in the first session and D-CS-2, D-CB-1, D-C95-5 and D-USP70-15 carrot samples in the second. The panellists were asked to indicate their preference for each sample, mainly based on texture and taste. A balanced 8-point hedonic rating was employed for all the attributes evaluated, where 1 denoted “like very much” and 8 indicated “dislike very much” (Sancho, Bota & de Castro, 2002). Similarly to data of section 2.4, overall scores obtained were compared by analysis of variance.

Data were subjected to analysis of variance (Fisher’s least significance difference (LSD) test) by applying the Statgraphics 4.0 program (Statistical Graphics Corporation, Rockville, Md) for Windows.

2.6. Discrimination analysis using the ChemSensor System (MS e-nose)

Dehydrated samples were ground and aliquots of 0.3 g of each treatment plus 300 µL of water were placed in a 10 mL vial and were hand-crimper sealed with an inert septum. DS-MS analyses were performed with a ChemSensor 4440B system (Agilent Technologies, Palo Alto, CA, USA), which can be considered as a MS electronic nose. It comprises of two modules. The first one is a 44-vial autosampler for headspace sampling (Agilent HS 7694) that includes an oven to heat the samples and to form the headspace (120 °C for 30 min), and a six-port injection valve with a 3-mL loop. Helium at 16 psi for 18 s was used for pressurizing the vial. The second module is a quadrupole mass spectrometer detector (MS5973N), operated in full scan mode (m/z 50-200) at 1.43 scans/s. The ionization energy was 70 eV. The transfer line, source, and quadrupole temperatures were set at 140, 230, and 150°C, respectively. Data were

acquired and a chemometric analysis was performed using Pirouette data analysis software (v3.11, Infometrix Inc., Bothell, WA).

Chemometric procedures. Matrix of m/z abundances was obtained from mass spectral fingerprints collected for every sample and subjected to statistical analysis. First, an unsupervised technique such as Principal Component Analysis (PCA) was applied in order to reduce the dimensionality of the data matrix and to find internal structures or clustering of data. Later, a supervised technique, Soft Independent Modeling Class Analogy (SIMCA), was used to obtain adequate classification procedures at the 95% confidence level. SIMCA develops principal component models to classify samples into discrete categories. It is based on the concept of proximity, the assumption that if a set of measurements for an unknown sample is very similar to that of a specific group, then the unknown is likely to be a member of that group. Although the ultimate goal of SIMCA is the reliable classification of new samples (i.e., unknowns), in this study SIMCA was used for discrimination of samples according to their processing. Thus, samples were visually classified by observing its position in the Coomans plot where the multiple thresholds divide the plot space into subregions of membership and not: a) the sample fits only one pre-defined category (a sample in the NW quadrant is a member only of the x axis class, and a sample falling in the SE quadrant is a member only of the y axis class); b) the sample does not fit any pre-defined categories (sample in the NE quadrant); c) the sample fits into more than one pre-defined category (sample in the SW quadrant) (Coomans, Broeckaert, Derde, Tassin & Massart, 1984).

3. Results and discussion

3.1. Effect of processing conditions on vitamin C

The retention of vitamin C is often used as an estimation of the overall nutritional quality of food products, particularly, vegetables (Goula & Adamopoulos, 2006). The losses of this vitamin are mainly attributed to its solubility in water and to its sensitivity to high temperatures and oxidation conditions (oxygen, pH and metal ions) (Davey et al., 2000). Table 2 shows the content of vitamin C (mg/100 g DM) and the corresponding percentages of vitamin retention of the different carrot samples (dried and/or blanched) analysed in the present study. The content of vitamin C of raw carrot was close to data previously reported by other authors (Negi & Roy, 2001; Frias, Peñas, Ullate & Vidal-Valverde, 2010).

Considering the effect of blanching, as can be seen in Table 2, the highest content of vitamin C, representing 85% retention of this vitamin, was found in CB-1 carrot sample. Frías et al. (2010) reported approximately the same retention level (80%) of vitamin C in samples of carrots subjected to the same blanching conditions. After CS-2 treatment, the percentage of retention was also very high (81%), and no significant differences ($p>0.05$) were found with respect to previous treatment. Drake et al. (1981) studied the influence of blanching method on the quality of selected vegetables and they found that water and steam blanched asparagus and green beans showed similar ascorbic acid concentration. Lin and Brewer (2005) observed in peas that steam blanching resulted in significantly better ascorbic acid retention than treatments with boiling water for equal blanching time. In the case of blanching treatments carried out at 95 °C for 5 min (C95-5) (Table 2), carrots presented a considerable reduction (62.5%) in the content of vitamin C. However, Shivhare, Gupta, Basu and Raghavan (2009), among the different assayed conditions, proposed this combination of temperature and

time together with 0.05 N acetic acid solution, as the best blanching treatment of carrots destined to juice elaboration. Lin, Durance and Scaman (1998) reported that blanching of carrots at 90 °C for 7 min before drying can preserve 57.5% of vitamin C content and Negi and Roy (2001) found 87.6% of retention of this vitamin after blanching of carrots at 95 °C for 90 s. In agreement with our experimental data, all these results highlight the great influence of small changes in blanching conditions (temperature, time, sample geometry, blanching water:carrot weight ratio, etc) on preservation of vitamin C content of carrots.

Regarding low temperature long time (LTLT) conventional blanching treatments, as shown in Table 2, C60-40 assay was the most drastic and resulted in the highest loss of vitamin C. These results could be explained by the noticeable leaching loss associated with long blanching times and/or the sample geometry, since C60-40 carrots were minced and presented higher specific surface than the slices used in the other conventional treatments (Table 1). In spite of the mild temperature used (60 °C), no oxidation of ascorbic acid due to residual ascorbic acid oxidase was suspected since, according to Rayan, Gab-Alla, Shatta and El-Shamei (2011), hardly any residual activity of this enzyme is presented under these experimental conditions.

In the case of carrot samples subjected to US blanching (Table 2), the loss of vitamin C was also very high, particularly in the case of USP60-10, which was close to 99%, as shown for C60-40 assay. These results are in agreement with the similar losses by leaching of total solids and soluble sugars and with the comparable results on inactivation of peroxidase and pectinmethylesterase previously reported for these samples (Gamboa-Santos et al., 2012). When USP60-10 and USP70-15 samples were compared, no significant differences ($p>0.05$) were found for the retention of vitamin C.

The main mechanism involved in the loss of vitamin C during US blanching treatments might be the formation of microchannels during cavitation which facilitate the transport of food constituents, especially soluble nutrients (Mothibe, Zhang, Nsor-atindana & Wang). In agreement with this, Opalic, Domitran, Komes, Belščak, Horžić, Karlović (2009) reported that prolonged US pretreatment in samples with the same geometry led to a decrease in total phenols and flavonoids as well as in the antioxidant capacity of dried apples.

The effect of drying on the retention of vitamin C of the different blanched carrot samples studied was also evaluated (Table 2). Since all samples were dried under the same conditions (46°C; 4.9 m/s), the observed variations in the final content of this vitamin (traces to 18.77 mg/100 g DM), as we have indicated above, were due to the different blanching procedures. The highest retention was found in D-CS-2 and D-CB-1 carrot samples; however, D-C95-5 carrot lost most of its content of vitamin C by leaching during blanching and the losses during dehydration were similar to those observed in D-CS-2 and D-CB-1 samples. With respect to the other samples analysed (D-C60-40, D-USP60-10, D-USP70-15), very low amounts of vitamin C were detected after drying since the prior blanching treatments were very severe.

The destruction of thermolabile vitamin C during the drying process was mainly due to the effect of drying time, since the temperature of the process was rather mild (46°C). In agreement with this, Mohamed and Hussein (1994) observed that ascorbic acid of carrot was easily damaged by long drying times, whereas carotenoids were more sensitive to drying temperature than to drying time. Negi and Roy (2001) reported 46% of vitamin C retention in carrots blanched at 95°C for 30 s after drying at 65°C whereas Frias et al. (2010) reported retention data of this vitamin within the range 43-50% in

carrot samples blanched in boiling water (60 s) and subsequently subjected to drying by convection at temperatures of 43-52°C for 6 hours.

3.2. Sensory evaluation

Sensory evaluation of the rehydrated carrot samples was carried out to obtain preliminary information on consumer's preference and product acceptance. Sensory assessment of dried samples was not performed, as Lin et al. (1998) found that colour, appearance, texture, aroma/flavour and overall acceptability of hot air-dried carrot slices were greatly improved when they were rehydrated and, moreover, dried carrots will mostly be consumed in rehydrated form.

In the triangle test, samples D-C60-40 and D-USP60-10 could not be distinguished in relation to the flavour and texture by the sensory panel since only 50% of panellists found the odd sample. The mean overall liking scores of the evaluated samples are shown in Table 3 and, as it can be observed, no significant differences ($p>0.05$) were found between the analysed samples. The score values were within the range 3.7 (close to "like slightly") for D-C60-40 and 3.2 (close to "like moderately") for D-USP60-10 carrot samples. When D-CS-2, D-CB-1, D-C95-5 and D-USP70-15 rehydrated carrot samples were compared in the hedonic scale (Table 3), the liking scores were similar among them and within the rating range "like moderately"- "like slightly", previously mentioned for the remaining samples here evaluated.

The obtained scores could be considered low for a highly appreciated product like carrots, but this fact could be explained considering the unavoidable losses of carbohydrates taking place mainly during blanching. Moreover, changes in volatile composition by evaporation, degradation, leaching and/or formation of new compounds

through blanching and processing could also support these results. In agreement with this, Shamaila et al. (1996) reported that blanching exerts a significant negative effect on the sensory attributes of carrots and their overall impression.

As it is well-known, carbohydrates together with volatiles are mostly responsible for the pleasant flavour and consumer acceptance of carrots (Alasalvar et al., 2001). Although no significant differences ($p>0.05$) were found, it is remarkable that the sample with the best score (3.0) was that corresponding to steam blanching (D-CS-2), probably due to the fact that this procedure has a lower impact on the losses of carbohydrates and volatiles than the conventional ones (Shamaila et al., 1996; Wang et al., 1997; Gamboa-Santos et al., 2012).

In general, the panellists highlighted the difficulty of the test since the assayed samples presented similar attributes and overall quality. Since drying and rehydration were the same in all cases, it seems that differences caused by blanching were minimized during the subsequent steps of processing. Similarly, Lin et al. (1998) found no significant differences in overall acceptability of rehydrated carrots previously blanched (at 90 °C during 7 min) and processed by air drying, vacuum microwave drying, and freeze-drying; however, differences were found when the non-rehydrated samples were compared.

Samples subjected to US blanching prior to drying by convection presented an acceptable quality, similar to that of carrots blanched by different conventional methods. Opalic et al. (2009), in a study on the use of an ultrasonic bath for 9-54 min for blanching of apples before drying, found a decrease in the sensory characteristics with the time of processing. When US were applied to osmotic drying of fruits, consumers preferred these samples because of their high sugar content (Mothibe et al., 2011).

3.3. Discrimination analysis using the ChemSensor System (MS e-nose)

Mass fingerprints obtained by using the ChemSensor methodology for samples under study (Table 1) were subjected to PCA in order to explore their unsupervised grouping. As shown in Fig 1 (PC1 vs PC2, 87.33% of variance explained), precision of the method was good for all the samples analysed, with scores corresponding to the same treatment being plotted close to each other. Considering the different blanching types assayed, only C60-40 pretreatment and its corresponding dehydrated carrots (D-C60-40) were plotted apart based on their high PC1 scores (> 50). On the other hand, from the similar location in this figure of blanched and their subsequently dehydrated carrots, it can be highlighted the higher impact of blanching conditions over identical dehydration on volatile composition of carrots, particularly for those samples processed under the most energetic conditions.

The scores plot of samples in Fig 1 also shows the coincidence of this classification with their vitamin C content. Thus, samples plotted at the right-bottom of this figure showed very low retention of vitamin C (C60-40, D-C60-40, USP70-15, D-USP70-15, USP60-10, D-USP60-10), whereas samples plotted at the left-top showed high retention of this vitamin (CB-1, CS-2, D-CB-1, D-CS-2, C95-5, DC95-5).

Based on ChemSensor testing using m/z intensity results, samples were visually classified by observing its position in Coomans plots. As example, Fig 2 shows some of them. Samples for every category clustered nicely, being this a prior requirement for its classification.

Regarding the effect of blanching in samples not further dried, the pairs of samples CS-2 vs CB-1 (Fig 2a), C60-40 vs USP60-10 (Fig 2b), USP70-15 vs CS-2 and USP70-15 vs CB-1 were clearly classified in the correct class. It is noteworthy that

samples subjected to similar blanching (CS-2 and CB-1) were properly separated in the Coomans plot. Similarly, different treatments (C60-40 and USP60-10) which gave rise to the same chemical changes during the leaching of components (Gamboa-Santos et al., 2012) were also correctly classified. Only some comparisons such as the pair USP70-15 vs C95-5 (Fig 2c) did not show an evident separation. Thus, whereas the USP70-15 samples were properly classified, the C95-5 samples were not, as they were borderline cases lying close to one of the thresholds.

When comparing carrots subjected to different blanching treatments and further dried under identical conditions, results were similar to those of non-dehydrated samples: D-CS-2 vs D-CB-1 (Fig 2a'), D-C60-40 vs D-USP60-10 (Fig 2b'), D-USP70-15 vs D-CS-2 and D-USP70-15 vs D-CB-1 were correctly classified, whereas samples D-USP70-15 vs D-C95-5 (Fig 2c') were not properly identified as members of its actual categories. It can be concluded from these results that blanching conditions were the predominant factor affecting the global volatile composition of carrots here analysed, all of them dehydrated under identical experimental conditions. Furthermore, Chemsensor results allowed the differentiation of samples indistinguishable for 50% of the members of the taste panel (Section 3.2; D-C60-40 vs D-USP60-10).

4. Conclusions

The high solubility in water of ascorbic acid makes the inevitable losses by leaching, associated to any of the blanching treatments assayed, responsible for the reduction to a certain extent of the content of this important vitamin. Taking into account the content of vitamin C, the samples with the highest retention were those subjected to conventional blanching at high temperature and short times. With respect to

samples subjected to US blanching prior to drying by convection, the most striking feature was their acceptable organoleptic quality, similar to that of carrots blanched by different conventional methods. The statistical analysis of mass spectral fingerprints gathered by the ChemSensor methodology allowed the differentiation of samples with a similar composition and/or blanching treatments, and indistinguishable for a taste panel of semi-trained judges. These results underline the usefulness of ChemSensor as a tool to classify processed carrot samples.

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550

551 **Figure captions:**

552

553 **Fig. 1.** Principal component biplot of mass spectral fingerprints corresponding to carrot
554 samples under analysis.

555 **Fig. 2.** Coomans plots. For identification of samples, see Table 1.